The Beagle, Occasional Papers of the Northern Territory Museum of Arts and Sciences, 1985, 2(1): 129-137

ON *BOTHRIOPLANA SEMPERI* FROM AUSTRALIA, WITH A REVIEW OF THE SPECIES (PLATYHELMINTHES, PROSERIATA, BOTHRIOPLANIDAE)

RONALD SLUYS AND IAN R. BALL
Institute of Taxonomic Zoology, University of Amsterdam, P.O. Box 20125, 1000 HC Amsterdam, The Netherlands.

ABSTRACT

The turbellarian *Bothrioplana semperi* Braun is recorded from Northern Australia for the first time. An account is given of what is known about the species' morphology, reproduction, ecology and distribution.

Keywords: Turbellaria, Proseriata, *Bothrioplana semperi*, morphology, reproduction, ecology, distribution, Northern Australia.

INTRODUCTION

The proseriate flatworm *Bothrioplana semperi* Braun, 1881, is the sole member of the family Bothrioplanidae and is known to have a wide-spread occurrence, but the species hitherto is unreported from Australia, New Zealand, Oceania and Antarctica (Du Bois-Reymond Marcus 1951). The present paper describes the collection of *B. semperi* near Darwin in Australia.

An account is given of the specimens collected, and also of the morphology of *B. semperi* as previously described in the literature. Identification of the species in whatever stage of development it may be encountered, should now be possible. Moreover, an overview is given of what is known of the species mode of reproduction, ecology and geographical distribution.

The specimens from Northern Australia are not in an ideal state of preservation but are satisfactory for identification. To facilitate further study of this animal in Australia, we have deposited the material examined in the Northern Territory Museum of Arts and Sciences (NTM), Darwin.

MATERIAL EXAMINED

NORTHERN TERRITORY: Manton Dam, 13°40′S 131°07′E, collected by I.R.Ball, 4 February 1983: NTM D.000001-1, sagittal sections on 1 slide; NTM D.000001-2, horizontal sections on 1 side; NTM D.000001-3, sagittal sections on 1 slide; NTM D.000001-4, sagittal sections on 1 slide; NTM D.000001-5, sagittal sections on 1 slide. Jabiru Mining Camp, Coonjimba Billabong, 12°42′S 132°54′E, collected by R. Marchant, 12 February 1980: NTM D.000002-1, sagittal sections on 1 slide; NTM D.000002-2, horizontal sections on 1 slide; NTM D.000002-3, sagittal sections on 1 slide; NTM D.000002-4, sagittal sections on 2 slides.

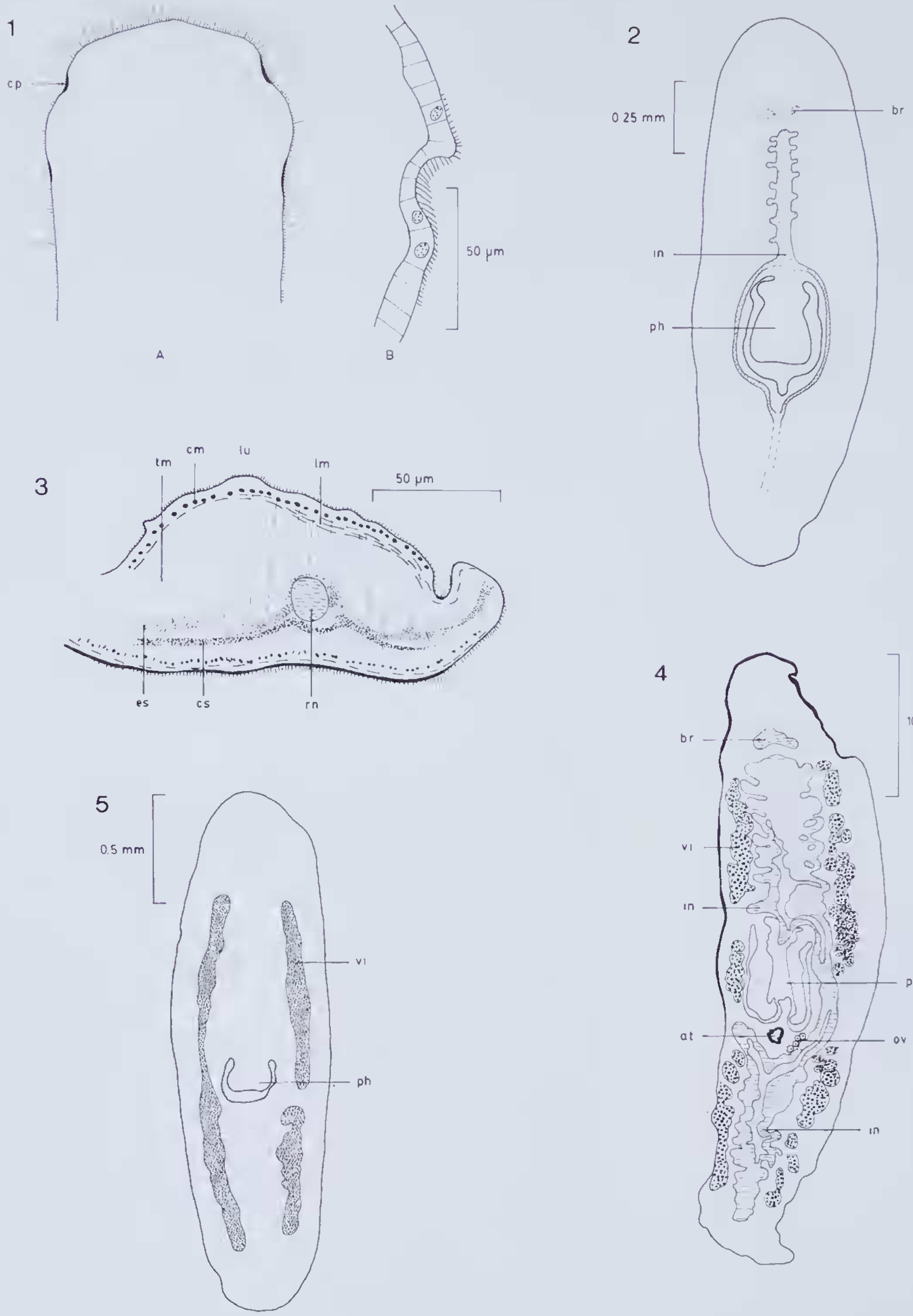
The animals from the Coonjimba billabong, collected by R. Marchant, are the 'Tricladida B' which this worker reported for five billabongs in the Northern Territory (Marchant 1982a, b).

Specimens from the Manton Dam were sectioned at intervals of 8 μm and stained in Mallory-Heidenhain, whereas those from the billabong were sectioned at 5 μm and stained in Azocarmine G.

MORPHOLOGY

The animals, lacking pigmentation, appear white. The body is elongate, with the hind and rounded and the front end truncate; the precise shape of the front end is variable in preserved specimens. *B.semperi* lacks eyes, but the front end carries two pairs of sensory or ciliated pits (Fig. 1A); young animals may show only the anterior pair of ciliated pits (Dahm 1951). These pits are merely shallow depressions of the body wall (Fig. 1B).

The preserved Australian specimens measured 1.9-2.5 mm in length and 0.6-1 mm in width. These dimensions are in agreement with the 2-3 mm lengths which Braun (1881) reported for his specimens (cited in Vejdovsky 1895). Other records



Figs 1-5. *Bothrioplana semperi*: **1A**, Front end (after Thienemann 1921), **1B**, Horizontal section of ciliated pit in NTM D.000001-2; **2**, Dorsal view of preserved specimen; **3**, Sagittal section of pharynx of NTM D.000001-5; **4**, Horizontal section of NTM D. 000001-2; **5**, Dorsal view of preserved specimen. Abbreviations: **at**, atrium; **br**, brain; **cm**, circular muscles; **cp**, ciliated pit; **cs**, cyanophilous secretion; **es**, erythrophilous secretion; **in**; intestine; **lm**, longitudinal muscles; **lu**; lumen; **ov**, ovary; **ph**, pharynx; **rn**, ring nerve; **tm**, transverse muscles; **vi**, vitellaria.

indicate a length of 3-4 mm (Hofsten 1907; Thienemann 1921; Holmquist 1972). According to Vejdovsky (1895) living specimens may be as long as 5-7 mm, and Marcus (1946) reported the animals as reaching a length of 7.5 mm and a width of 1 mm.

The body wall is underlain with an outer layer of circular muscles and inner layer of longitudinal muscle fibres. According to Hofsten (1907) a layer of diagonally running muscle fibres is interpolated between these two muscle layers; we were unable to discern this diagonal layer in our preparations.

Many of the nucleate and ciliated epidermal cells are penetrated by conspicuous, densely red staining, packages of rhabdites, originating from large, also densely staining rhabdite-forming glands which lie in the parenchyma just beneath the epidermis. The rhabdites stick closely together and are hardly distinguishable individually. At the front end, the ventral epidermis is penetrated by an erythrophilous, granular, secretion which comes from glandular elements which lie well within the parenchyma. These gland cells represent the so-called frontal organ. The secretion is discharged between the epidermal cells and not through specialized cells.

The short pharynx lies in the middle of the body (Fig. 2) and its histology is as follows (Fig. 3). Beneath its ciliated inner epithelium there is a single row of circular muscle fibres which is bounded interiorly by a layer of longitudinal muscles; the outer pharynx epithelium, which is also ciliated, is underlain with an outer layer of longitudinal muscles and a single inner row of circular muscle fibres. The pharynx is also traversed by transverse muscle fibres and by bands of erythrophilous and cyanophilous secretion. The mouth opening is situated almost at the hind end of the pharyngeal pocket.

B.semperi possesses a characteristic tripartite intestine. The anterior branch of the gut terminates behind the brain, and the two posterior trunks unite behind the copulatory apparatus into a single branch (Figs 2,4).

The male copulatory system (Fig. 6) is of a very simple and highly reduced construction. The extent of reduction varies between specimens and may even amount to the complete absence of the male reproductive organs. According to Reisinger (1940) 90% of middle European specimens completely lack the male organs under optimal feeding conditions.

The paired, rather small, testes are situated dorso-laterally on either side of the pharynx; they occur at the level of the posterior portion of the pharyngeal cavity. It is not uncommon for one testicular follicle to be completely absent or highly reduced (Vejdovsky 1895; Hofsten 1907; Du Bois- Reymond Marcus 1951). From each of the follicles arises a vas deferens which opens into a ciliated seminal vesicle which in turn empties into a granular seminal vesicle. The latter opens into the atrium through a very small penis papilla.

The above description of the male reproductive system is based on Hofsten (1907) and illustrated in Fig. 6. In a single specimen one may not encounter all of the structures of the male system mentioned above. It may happen that a single functioning testis is situated so close to the penis that a vas deferens is virtually absent (cf. Du Bois-Reymond Marcus 1951, Fig. 9: a sagittal section and not, as indicated, a transverse one). The Australian specimens had very poorly developed testes containing at most a number of seminal filaments or large spermatocytes. Sperm production in *B. semperi* and is lined with ciliated cells.

So-called cement glands surround the gonopore and discharge their secretion into the latter. These glands were observed also by Vejdovsky (1895), Marcus (1946) and Du Bois-Reymond Marcus (1951) but were not described by Hofsten (1907).

The vitellaria are usually well developed and may already be visible in preserved specimens as two brownish bands (Fig. 5). The follicles are situated laterally to the intestine and extend from behind the brain into the hind end of the body (Fig. 4).

The paired ovaries are situated ventrally at either side of the genital atrium, and they consist of a row of oocytes in different states of maturation

(Fig. 7). The oviducts unite to a common oviduct which empties into the female genital duct or glandular duct. This duct is merely a diverticulum of the genital atrium which is penetrated by the openings of shell glands. The female genital duct communicates with the intestine through a genito-intestinal duct (Fig. 5).

The nervous system of *B. semperi* has been examined by Reisinger (1925), and some of his results are summarized in Bresslau (1933: 79-80). The species has four pairs of longitudinal nerve cords comprising one pair of ventral cords, a pair of dorsal nerve cords, a pair of lateral nerve cords, and a pair of ventro-lateral nerve cords, all of them being connected by means of ring-shaped commissures.

REPRODUCTION

As mentioned above, the testes of *B. semperi* usually do not function and when they do, spermiogenesis is abnormal, resulting in sterility of the spermatids (Reisinger 1940). Nevertheless, the species reproduces sexually, through parthenogenesis. Two egg cells, one from each ovary, are combined with numerous yolk cells in a cocoon, which is formed in the atrium. Only one embryo develops parthenogenetically from these two oocytes, a process described under the name of parthenogenetic dioogony (Reisinger 1940).

As may be expected, oogenesis shows some unusual features. In *B. semperi* somatic cells and newly formed oocytes contain 2n=20 chromosomes. Via a complex series of divisions the two oocytes which are assembled in the cocoon, give

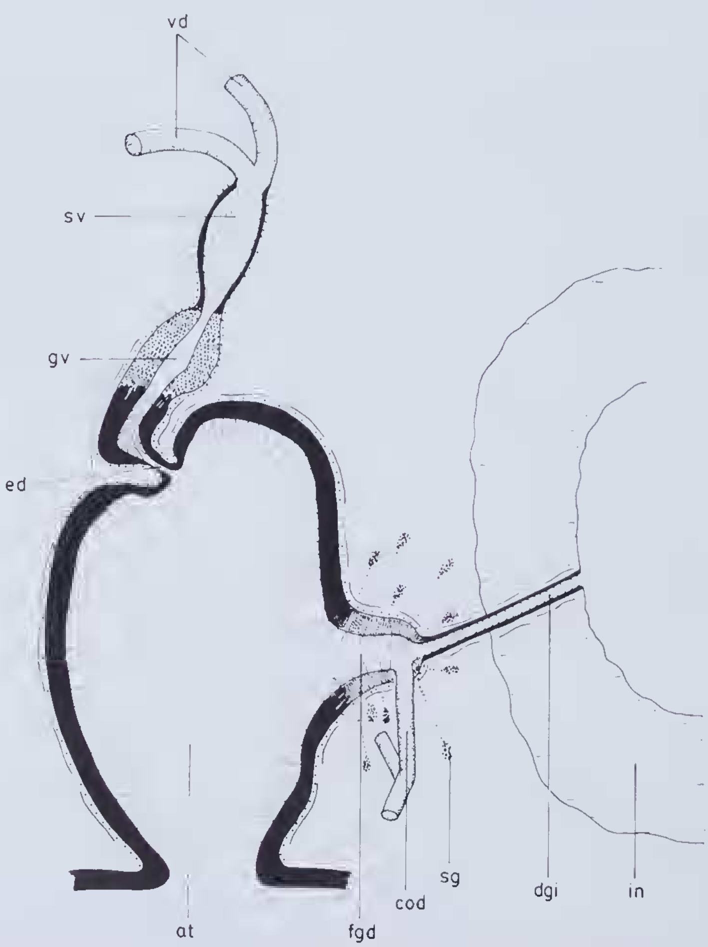


Fig. 6. *Bothrioplana semperi*, diagrammatic sagittal reconstruction of copulatory apparatus (after Hofsten 1907; Reisinger 1923). Abbreviations: **at**, atrium; **cod**, common oviduct; **dgi**, genito-intestinal duct; **ed**, ejaculatory duct; **fgd**, female genital duct; **gv**, granular vesicle; **in**, intestine; **sg**, shell glands; **sv**, seminal vesicle; **vd**, vas deferens.

rise to 8 cells each with a chromosome complement of 2n=20. These 8 cells are actually blastomeres and give rise to the embryo (Reisinger 1940). The division process has been summarized in Reisinger *et al.* (1974) and in Benazzi and Benazzi-Lentati (1976).

ECOLOGY

B. semperi has been collected from various types of biotopes. The species has been found most often in the mud of stagnant pools and wells (Thienemann 1921; Dahm 1951); frequently these habitats had contact with the ground water but *B. semperi* is no pure ground water species (Reisinger 1925) since it may be found also in temporary pools which are fed by rain fall or by the outflow from lakes. The species has been collected also from turfs of moss at the borders of lakes or rivers (Steinböck 1928; Dahm, 1951), and from among the moss growing on stones in rapidly running rivers and brooks (Steinböck 1928). In Norway *B. semperi* has been dredged from a lake at a depth of 40-41 m (Holmquist 1972), and in Japan it has been collected from subterranean lakes (Mack-Fira and Kawakatsu 1972). With respect to its vertical distribution, *B. semperi* has been collected from water bodies at elevations up to 1500 m (Reisinger 1925).

Very little data have been published on the physico-chemical characteristics of the various habitats from which *B. semperi* has been collected, so that detailed comparisons of habitat differences in relation to aspects of the species life history are virtually impossible. A few authors have reported on temperature and pH. Dahm (1951) found the species in localities ranging from 9.3° C to 17° C, whereas the pH ranged from 5.6 to 7.4. In the Norwegian lake from which Holmquist (1972) obtained her specimens, the temperature varied from 4° C to 12° C. The two subterranean sample localities of Mack-Fira and Kawakatsu (1972) were characterized by a temperature of 9° C and 11° C and pH 6.8 and pH 6.2, respectively. Marchant (1982a, b) reported that as a result of seasonal variation the temperature of the surface water in the five billabongs varied between a July minimum of 22° C and a November maximum of 38° C, whereas the pH of these waters varied between 6.0 and 7.0, According to Dahm (1951) rapid temperature changes, within limits of 0-25° C, have little influence on *B. semperi*.

The specimens from Manton Dam were collected from a pool below a dam wall. The pool appeared most sterile, lacked vegetation and contained iron-coloured water of a surprisingly high temperature.

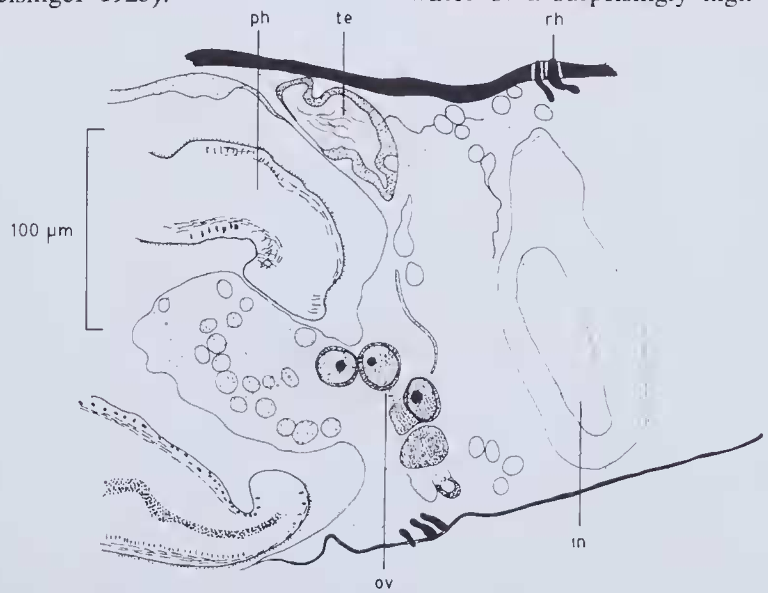


Fig. 7. *Bothrioplana semperi*, saggittal section of NTM D.000001-1. Abbreviations: **in**, intestine; **ov**, ovary; **ph**, pharynx; **rh**, rhabdite- forming gland; **te**, testis.

Fig. 8. Number of specimens of *B. semperi* in monthly counts, by standardized sampling procedure, of five billabongs in Northern Territory (combined after Marchant 1982b).

It was already known from statements in the literature that local population densities of *B. semperi* may vary greatly (Dahm 1951). These variations are due to seasonal influences. Marchant (1982a, b) monitored by means of monthly counts by a standardized sampling procedure the abundance of, among others, *B. semperi* in five billabongs in the Northern Territory (Marchant's 'Tricladida B' is here assigned to *B. semperi*, sec Material Examined). We have combined the results of the five billabongs and have summarized the data in Fig. 8. It is evident that the period with the greatest number of individuals coincides with the wet season (December- April) and that especially in January, when the water levels start to rise, the number of individuals increases rapidly. It is important to note however, that during the year none of the billabongs became dry (Marchant 1982a).

All this is also consistent with the observation of Ball that whereas in November 1982 no specimens were found at the Manton Dam, in February 1983 *B. semperi* was the dominant turbellarian.

DISTRIBUTION

B. semperi has a wide, probably cosmopolitan, distribution (Fig. 9); it is likely that the apparent North-South disjunction reflects but the distribution of collectors. This wide distribution of *B. semperi* may be due to the fact that the species has some traits which may enhance successful dispersal (Dahm 1951). For example, animals may encapsulate in a thin capsule of slime, thus being protected to some degree against desiccation for a short period of time. Furthermore, their cocoons have a strong wall and may facilitate long-distance biochore or anemochore dispersal, although the capsules are not able to withstand severe periods of desiccation (Reisinger 1925; Dahm 1951). The chance of successful colonization is enhanced by the fact that *B. semperi* is able to thrive in a variety of habitats and also by its mode of reproduction.

It should be noted, however, that there are turbellarians with similar capacities which, nevertheless, have a restricted distribution. For example, some freshwater planarians which live in temporary pools are able to encyst and one produces a resistant cocoon, yet these species are far from cosmopolitan in their distribution (cf. Ball, Gourbault and Kenk 1981). What dispersal methods *B. semperi* employs are not known but its peculiar mode of reproduction and ecological versatility would favour colonisation of new habitats.

DISCUSSION

Both Reisinger (1925) and Dahm (1951) have summarized information on the two genera and four to six species of Bothrioplanidae which had been described by previous authors. Both authors came to the conclusion that there is only one Bothrioplanid species. *B. semperi* Braun, 1881. The apparent lack of geographical variation, despite possible isolation of populations and parthenogenetic reproduction, could be explained by a situation wherein differentiation took place on a cytological or biochemical level, and not in morphology (Dahm 1951). The great variety of habitats suggests that individuals may be heterozygous across a wide range of loci, thus enabling them to cope with a broad spectrum of environmental parameters. Here is a potential tool

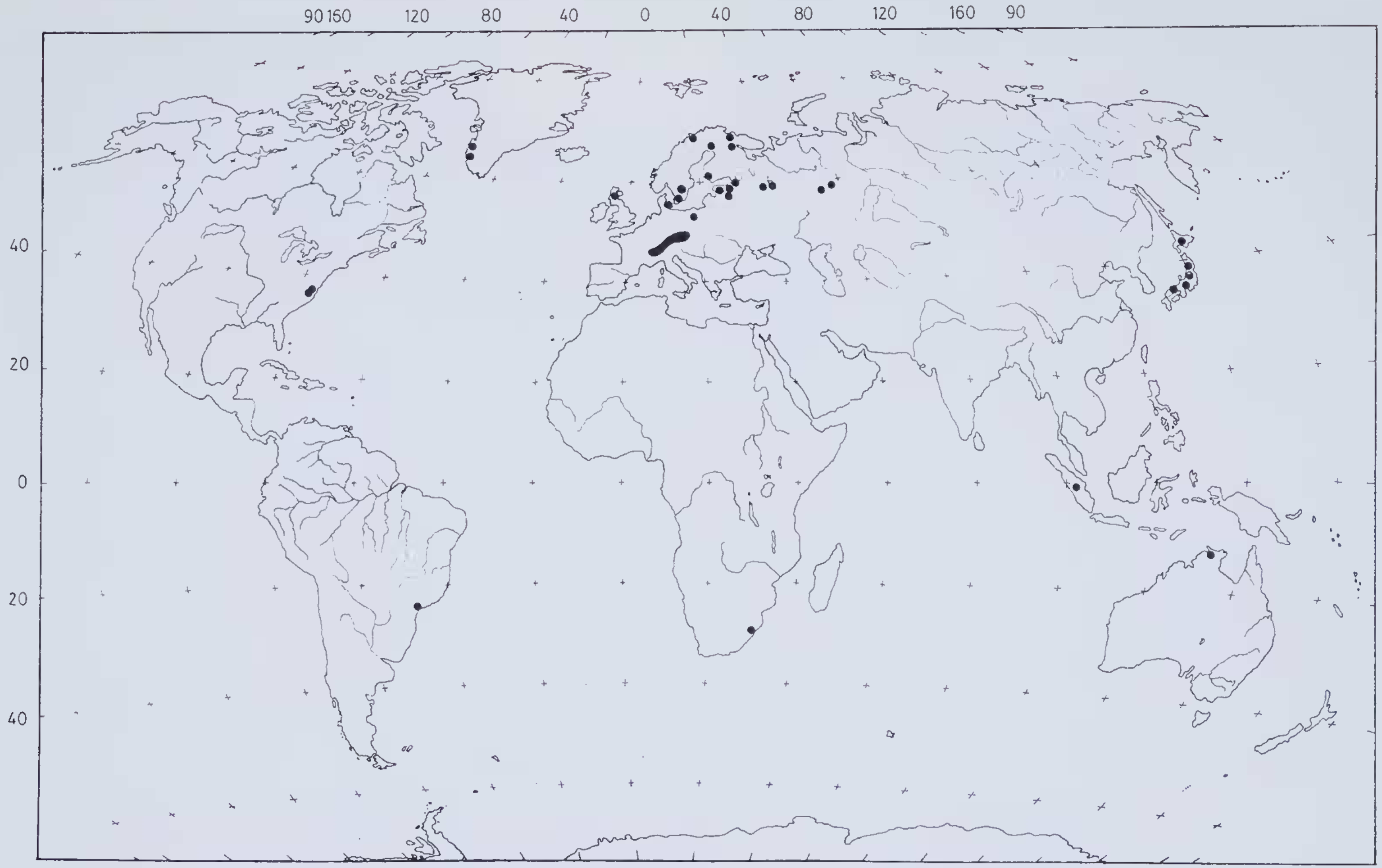


Fig. 9. Geographical distribution of *Bothrioplana semperi*. After Carter (1929), Dahm (1951), Du Bois- Reymond Marcus (1951), Ferguson *et al.* (1939), Holmquist (1972), Kolasa (1974), Mack-Fira and Kawakatsu (1972), Marcus (1946), Reisinger (1933), material examined.

for research into aspects of niche dimensions and heterozygosity in flatworms.

In view of the above, it is interesting that Kawakatsu and Mack-Fira (1975) described a *Bothrioplana* sp. from the Nagasaki district in Japan, which differs in certain respects from the description of *B. semperi* provided above. The animals looked like *B. semperi* at first sight, but showed a very large brain with a completely different appearance than that of *B. semperi*. The latter has a much smaller brain with a very characteristic shape (cf. Reisinger 1925, Fig. 6; Marcus 1946, Fig. 138; Bresslau 1933, Fig. 90, the latter reproduced in Beauchamp 1961, Fig. 64). Moreover, the male copulatory apparatus of *Bothrioplana* sp. appeared to be well developed, consisting of a large intrabulbar seminal vesicle and a large, muscularized, penis papilla. Ovaries and testes were absent, but the course of the vasa deferentia suggested that the testicular follicles are located much more anteriorly than is the case in *B. semperi*.

ACKNOWLEDGEMENTS

This paper is a byproduct of IRB's research programme on the aquatic planarians of Australia supported by the Australian Biological Resources Study, and administered through the Department of Zoology of the University of Adelaide. Additional support for fieldwork in northern Australia came from the Treub Maatschappij, The Netherlands. The facilities of the Northern Territory Museum of Arts and Sciences were graciously made available by Dr A J Bruce, and he and Mr Ian Archibald made possible the collecting trips. For all this help we are grateful. We also thank Dr R Marchant of the Museum of Victoria for placing his material at our disposal.

REFERENCES

Ball, I.R., Gourbault, N. and Kenk, R. 1981 The planarians (Turbellaria) of temporary waters in eastern North America. *Life Science Contributions Royal Ontario Museum* **127**: 1-27.

Beauchamp, P. de 1961 Turbellaria. In: P.P. Grassé (ed) *Traité de Zoologie* Tome 4. Masson et Ciestet: Paris.

Benazzi, M. and Benazzi Lentati, G. 1976 *Animal Cytogenetics I. Platyhelminthes*. Gebr. Borntraeger: Berlin, Stuttgart.

Braun, M. 1881 Über Dorpater Brunnenplanarien (Beiträge zur Kenntnis der Fauna Baltica. I). *Archiv für die Naturkunde Liv-, Esth- und Kurlands* **2** (9): 289- 343 (not seen in original).

Bresslau, E. 1933. Turbellaria. In: W. Kükenthal and T. Krumbach *Handbuch der Zoologie* Bd. II. Erste Hälfte, W. de Gruyter & Co. : Berlin, Leipzig.

Carter, J.S. 1929 Observations on Rhabdocoels of Albemarle County, Virginia. *Transactions of the American Microscopical Society* **48** (4): 431-437 (not seen in original, cited in Marcus, 1946).

Dahm, A. G. 1951 On *Bothrioplana semperi* Braun (Turbellaria Alloeocoela Cyclocoela). *Arkiv för Zoologi* **1**: 503-510.

Du Bois-Reymond Marcus, E. 1951 Two freshwater Turbellaria from Natal. *Annals of the Natal Museum* **12**: 73-80.

Ferguson, F.F., Stirewalt, M.A., Brown, T.D. and Hayes, W.J. jr. 1939 Studies on the turbellarian fauna of the Mountain Lake Biological Station I. Ecology and distribution. *Journal of the Elisha Mitchell Scientific Society* **55**: 274-288.

Hofsten, N. von 1907 Studien über Turbellarien aus dem Berner Oberland. *Zeitschrift für wissenschaftliche Zoologie* **85**: 391-654.

Holmquist, C. 1972 Nagra interessanta fynd av sötvattensturbellarier i Norge. *Fauna (Oslo)* **25** (3): 205-212.

Kawakatsu, M. and Mack-Fira, V. 1975 The fauna of the insular lava caves in West Japan II. Proseriata et Tricladida (Turbellaria). *Bulletin of the National Science Museum* (Tokyo) **1** (2): 77-84.

Kolasa, J. 1974 Badania nad wirkami (Turbellaria) zrodel ze szczegolnym uwzgledniemniem okolic Poznania. *Badania Fizjograficzne nad Polska zachodnia (Biol., seria B)* **26**: 7-31 (not seen in original).

Mack-Fira, V. and Kawakatsu, M. 1972 The fauna of the lava around Mt. Fuji-san I. Proseriata et Tricladida (Turbellaria). *Bulletin of the National Science Museum (Tokyo)* **15** (4): 637-646.

Marchant, R. 1982a Seasonal variation in the macroinvertebrate fauna of billabongs along Magela Creek, Northern Territory. *Australian Journal of Marine and Freshwater Research* **33**: 329-342.

Marchant, R. 1982b *The macroinvertebrates of Magela Creek, Northern Territory*. Supervising Scientist for the Alligator Rivers Region. Report 1. Australian Government Publishing Service: Canberra.

Marcus, E. 1946 Sôbre Turbellaria brasileiros. *Universidade de S. Paulo, Boletins de Faculdade de Filosofia, Ciências e Letras, Zoologia* **11**: 5-187.

Reisinger, E, 1923 Turbellaria. In: P. Schulze (ed) *Biologie der Tiere Deutschlands* **6** (4): 1-64.

——— 1925 Untersuchungen am Nervensystem der Bothrioplana semperi Braun. *Zeitschrift für Morphologie and Ökologie Tiere* **5**: 119-149.

——— 1933 Turbellaria der Deutschen Limnologischen Sunda-Expedition. *Archiv für Hy-*

drobiologie und Planktonkunde 1933, Supplementband **12**: 239-261.

——— 1940 Die cytologische Grundlage der parthenogenetischen Dioogonie. *Chromosoma (Berlin) Abt. B* **1**: 531-553.

Reisinger, E., Cichocki, I., Gerlach, R. and Szyskowitz, T. 1974 Ontogenetische Studien an Turbellarien: ein Beitrag zur Evolution der Dotterverarbeitung im ektolecitalen Ei. 2 Teil. *Zeitschrift für zoologische Systematik und Evolutionsforschung* **12** (4): 241-278.

Steinböck, O. 1928 Beiträge zur Kenntnis der Turbellarienfauna Grönlands I. Bothrioplanida und Tricladida. *Meddelelser om Grönland* **74**: 71-82.

Theinemann, A. 1921 Über *Euporobothria bohemica* (Vejd.). *Zoologischer Anzeiger* **53** : 120-123.

Vejdovsky, F 1895 Zur vergleichenden Anatomie der Turbellarien. *Zeitschrift für wissenschaftliche Zoologie* **60**: 90-214.

Accepted 25 June 1985